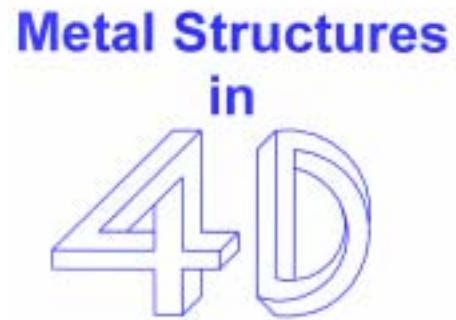


Current and Future Applications of 3DXRD Microscopy within Materials Science

Dorte Juul Jensen

**Center for Fundamental Research:
Metal Structures in Four Dimensions
Risø Denmark**

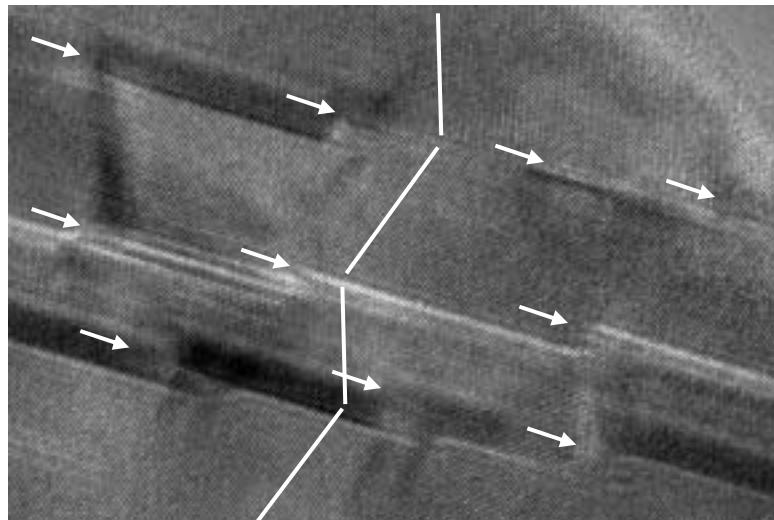


Aims

- **3D**
- **μm spatial resolution**
- **fast**

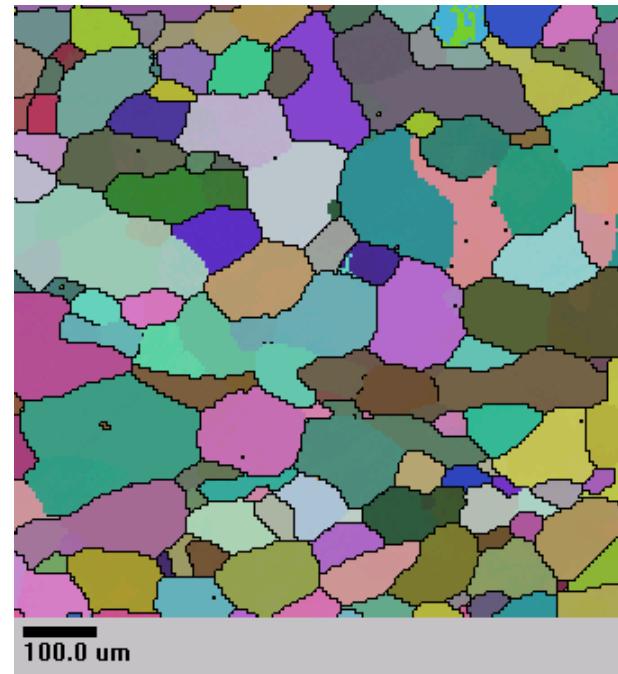
2D microscopy

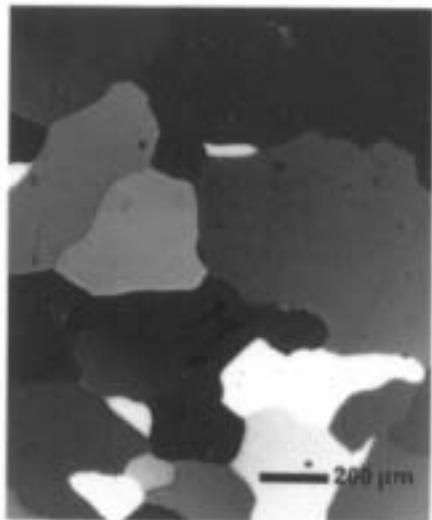
High resolution TEM



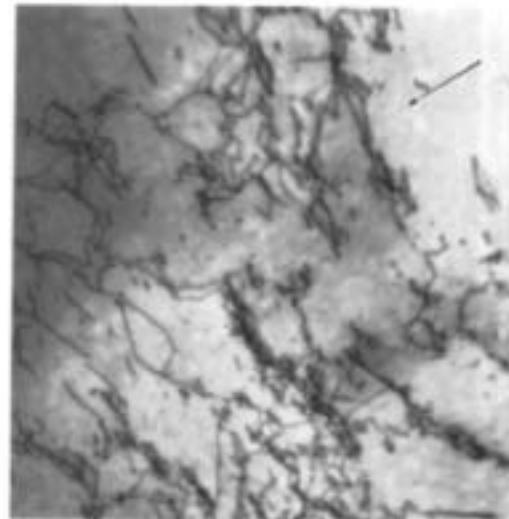
Shockley partials along
twin boundaries, Cu

EBSP map



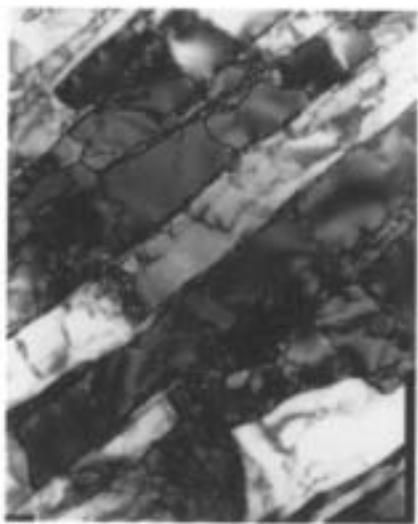


stress

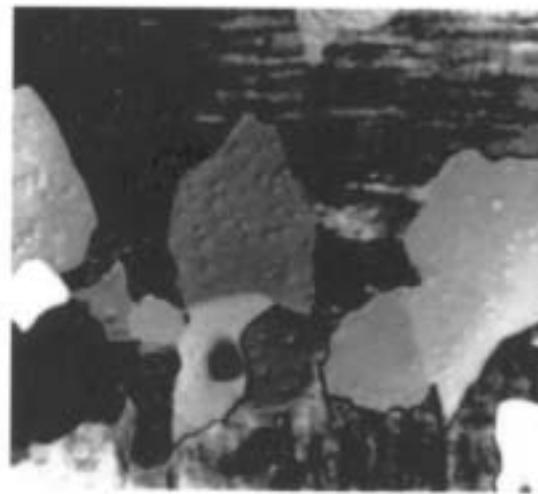


200μm

2μm



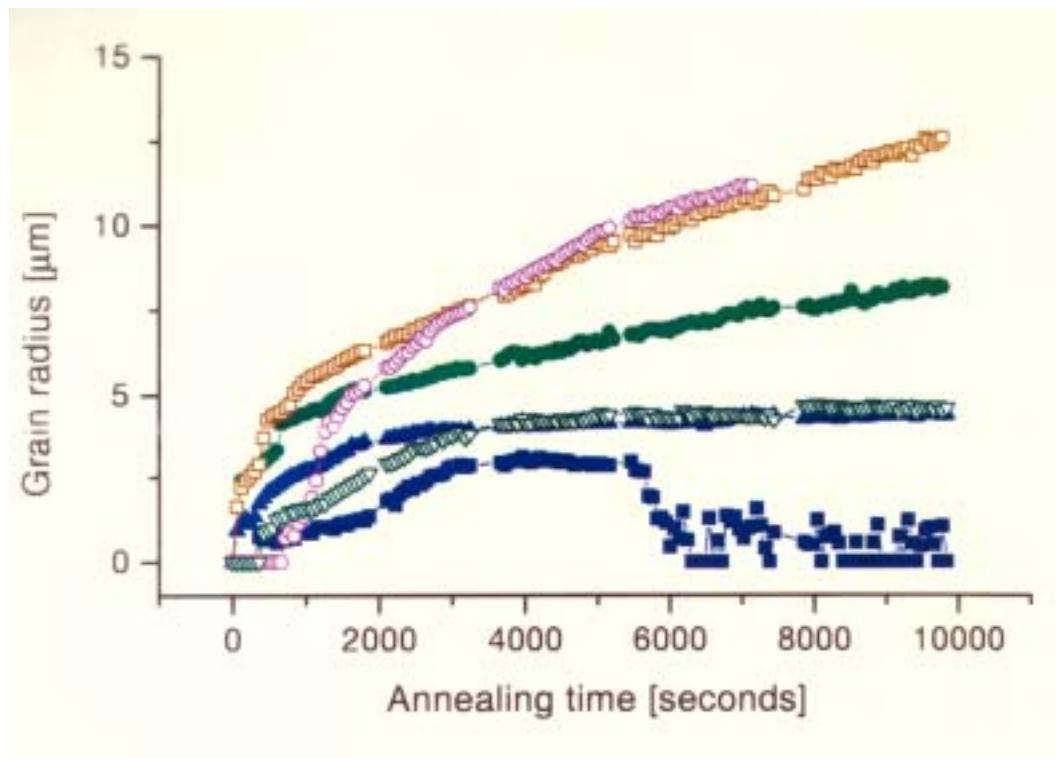
heat



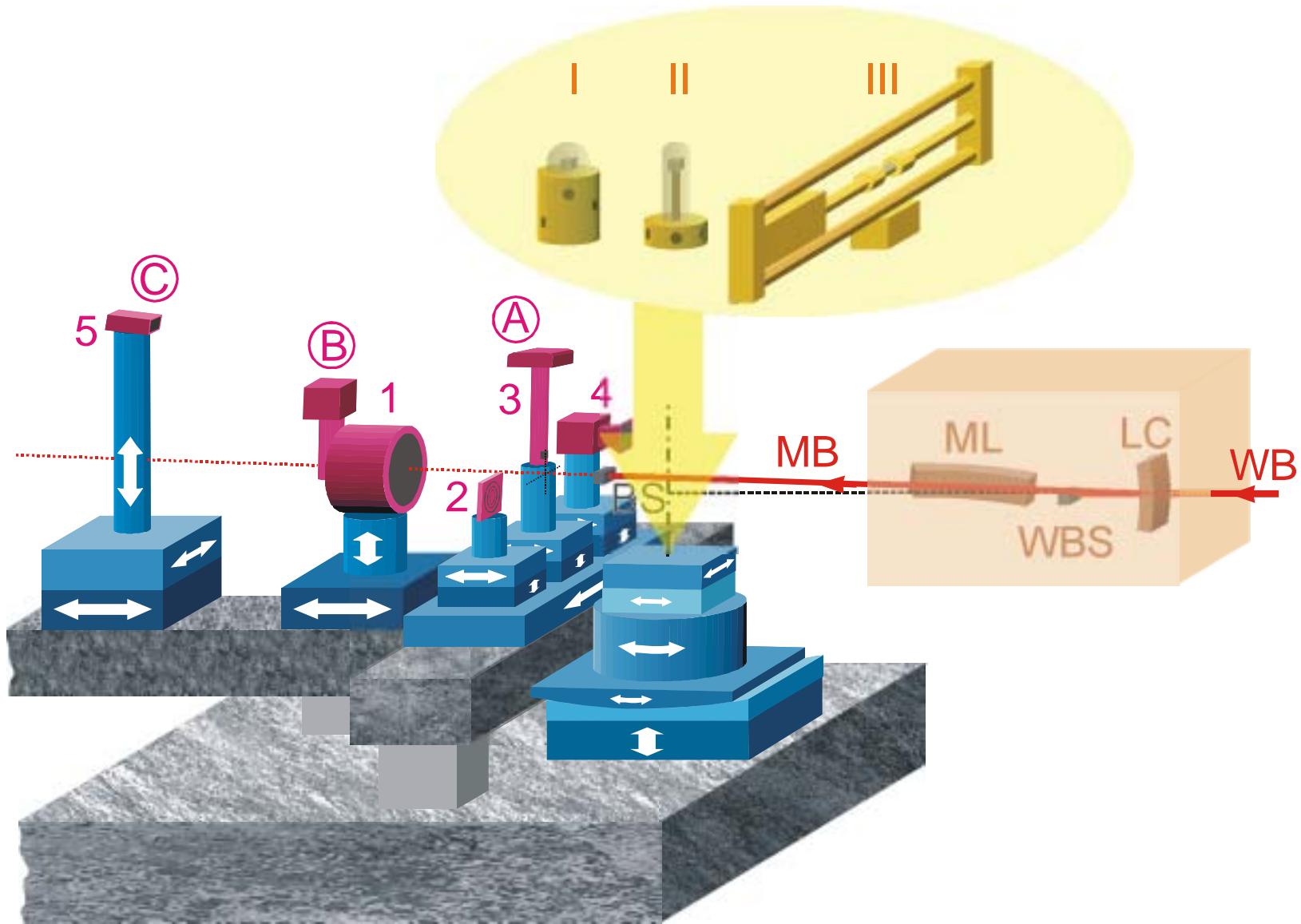
5μm

20μm

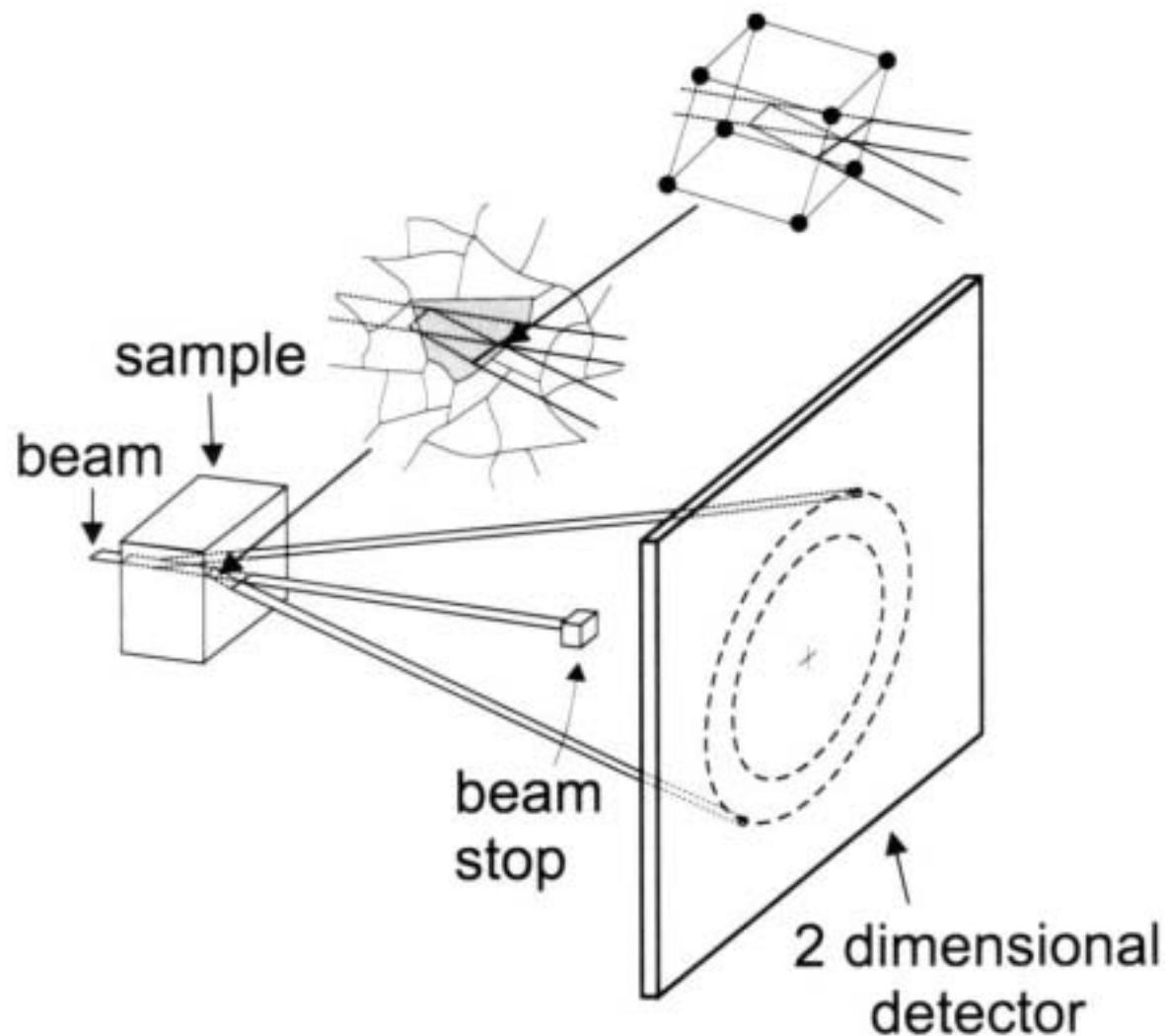
In-situ investigations of Dynamics

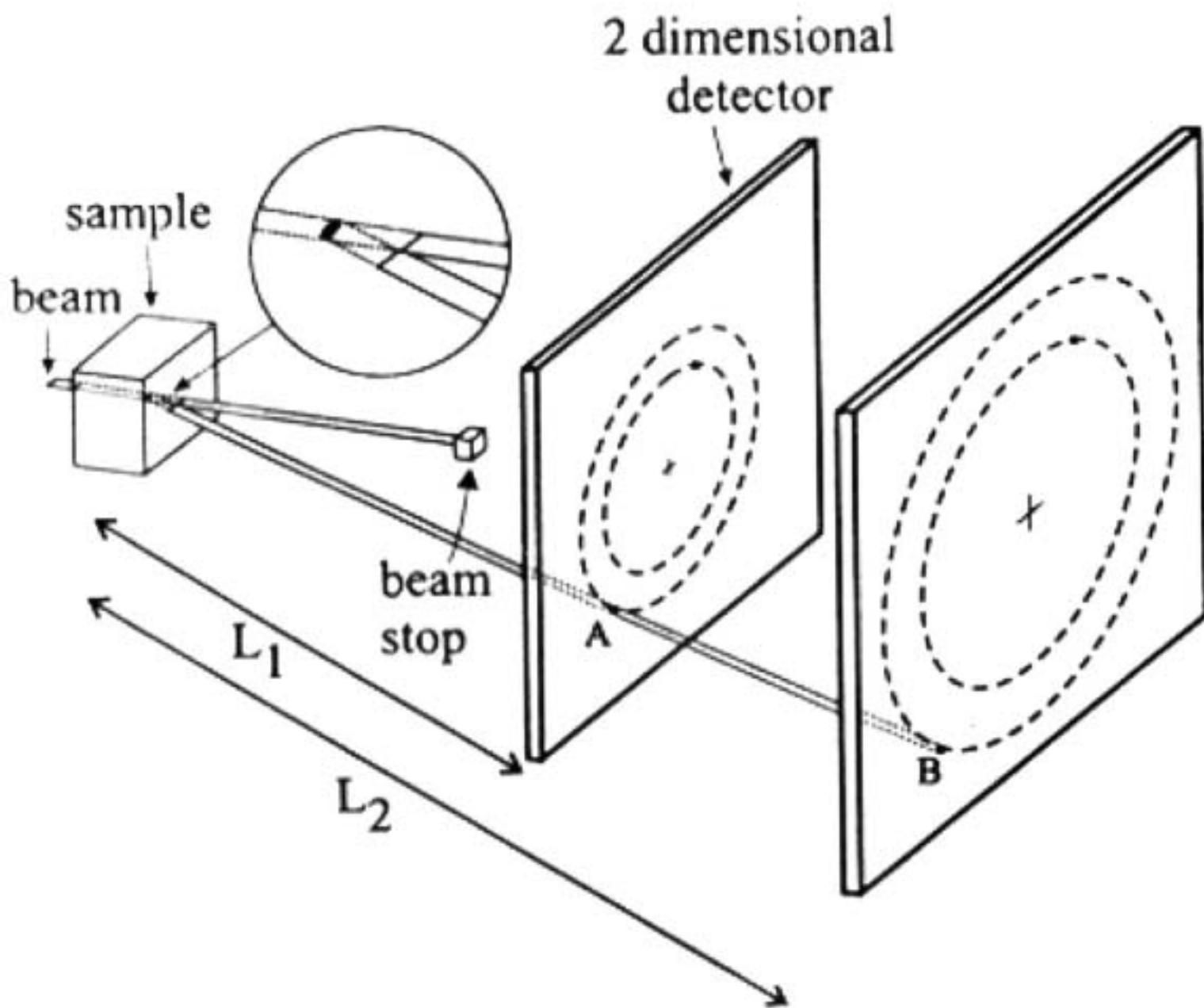


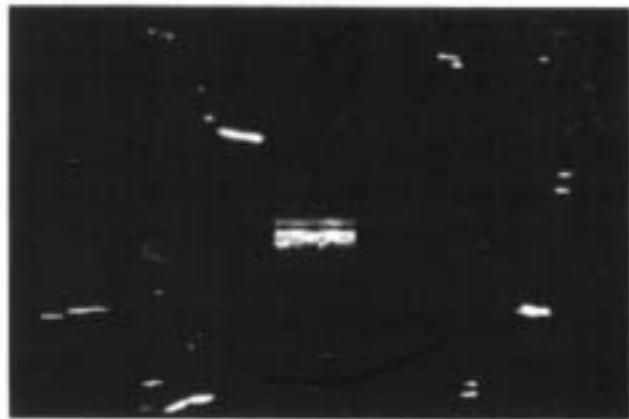
Time resolution seconds-minutes









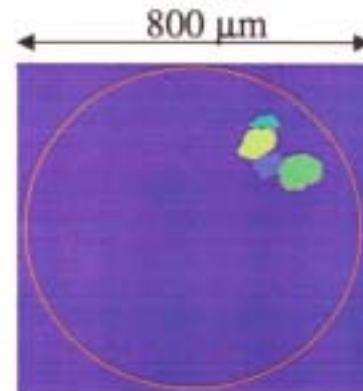


Distance from
sample to
detector

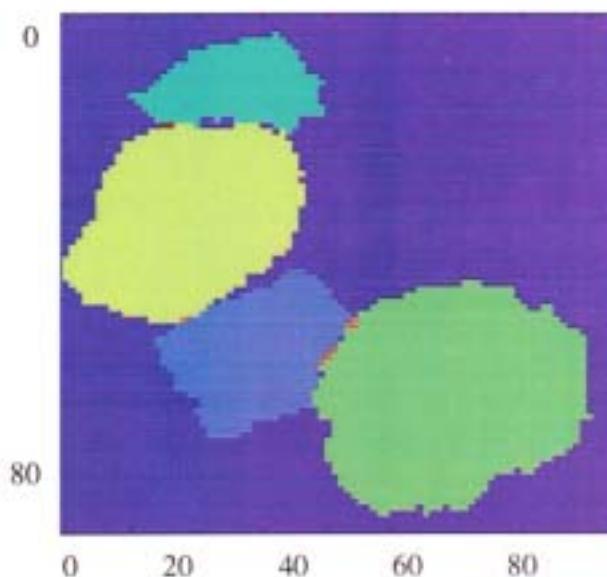
Reconstruction by ART

Solve: $Wa = b$

Ex: Al sample,
pixel size $2.3 \mu\text{m}$,
Point-spread-function: $6 \mu\text{m}$
8 min per layer:



Zoom:



Spatial resolution: $\sim 3 \mu\text{m}$

3DXRD Specifications

Experimental Conditions:

- Energy Range 50 – 100 keV
- Flux $10^{11} - 10^{12}$ p/s

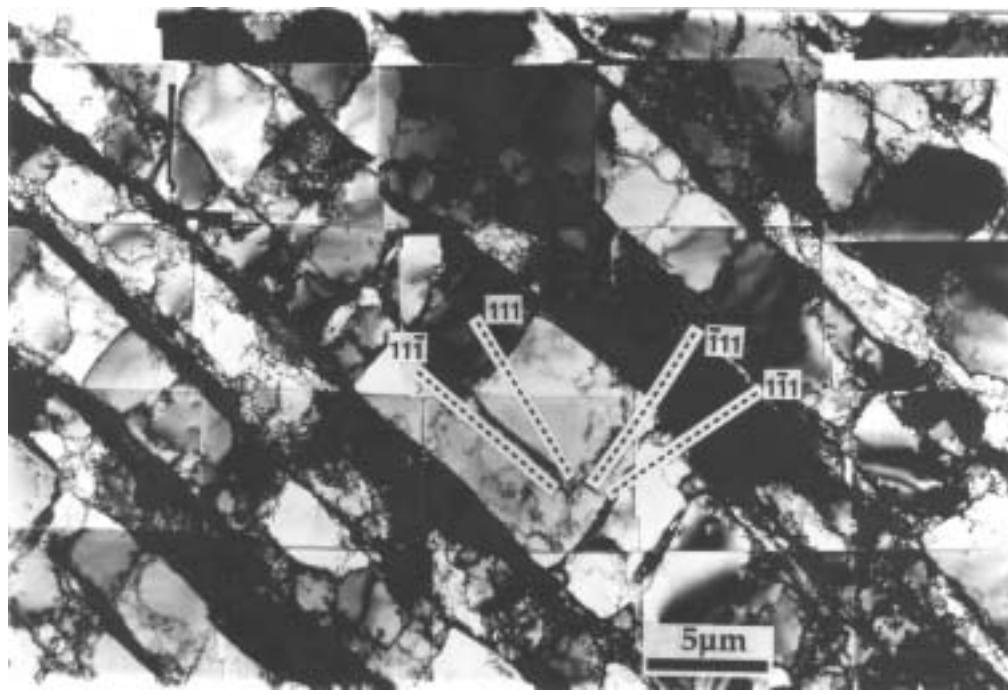
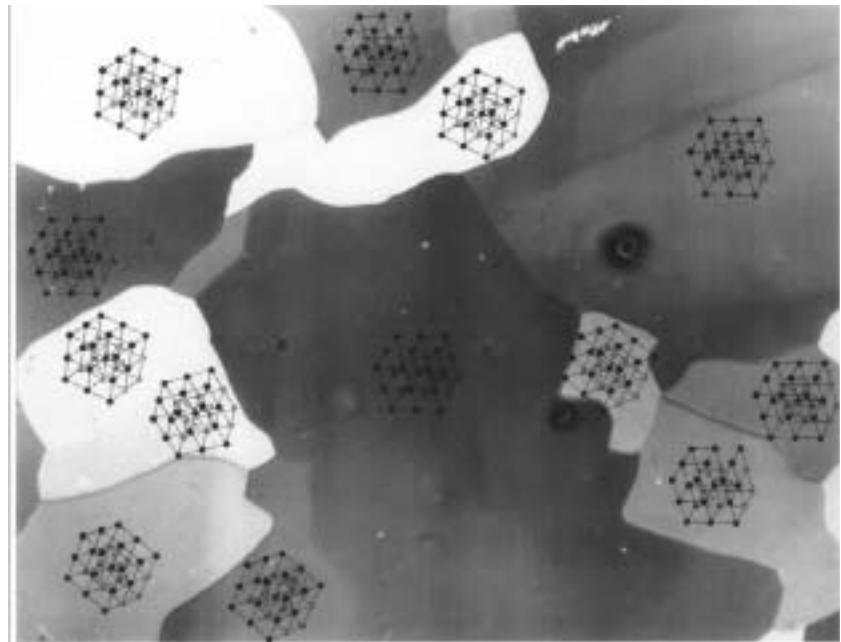
Measurements of:

- Position and Volume
- Crystallographic Orientation
- Elastic Strain
- 3D Shape

Spatial Resolution

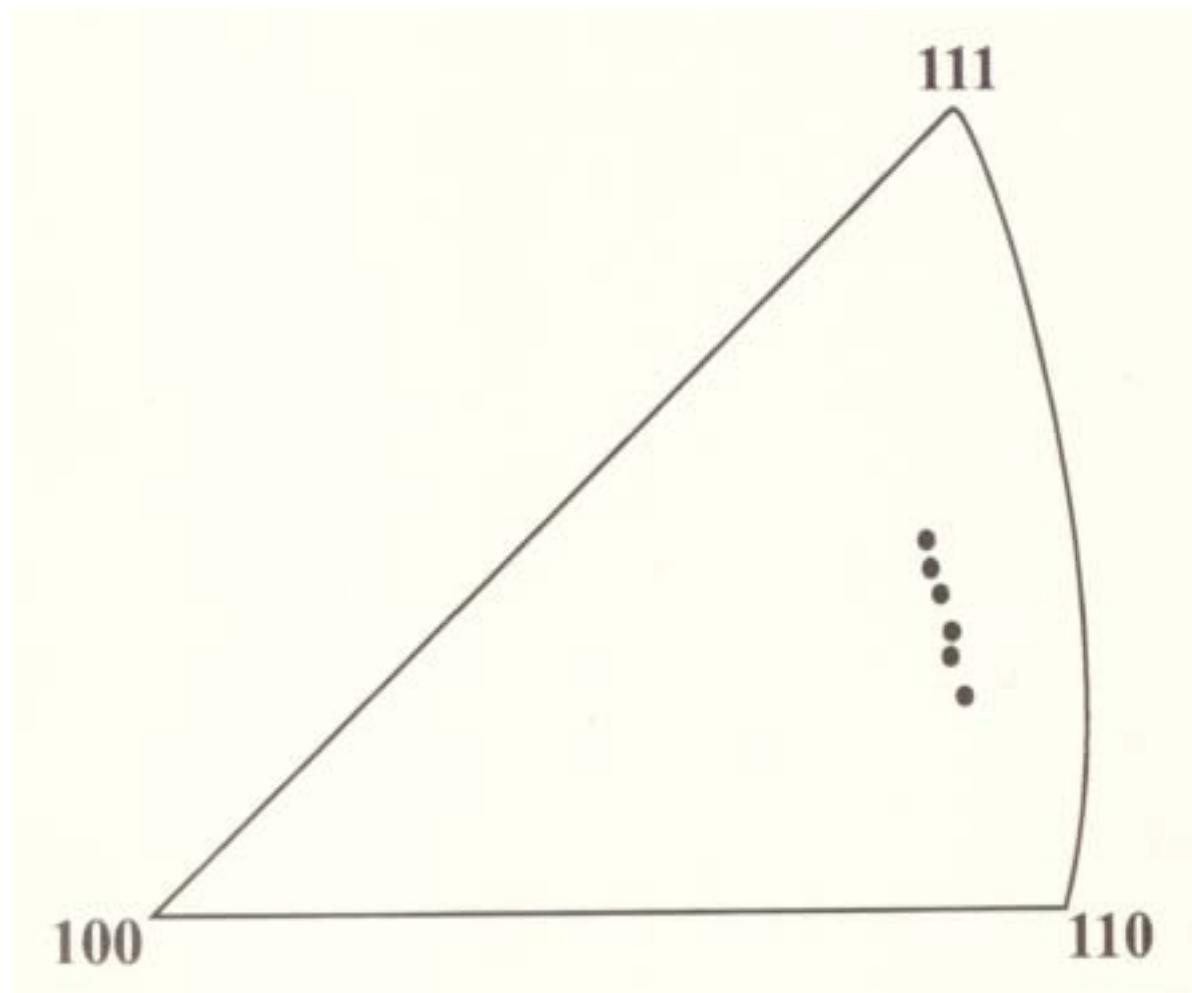
- Mapping Precision $1\mu\text{m} \times 5\ \mu\text{m} \times 5\ \mu\text{m}$
- Min. Size $0.15\ \mu\text{m}$ (no mapping)

Plastic Deformation



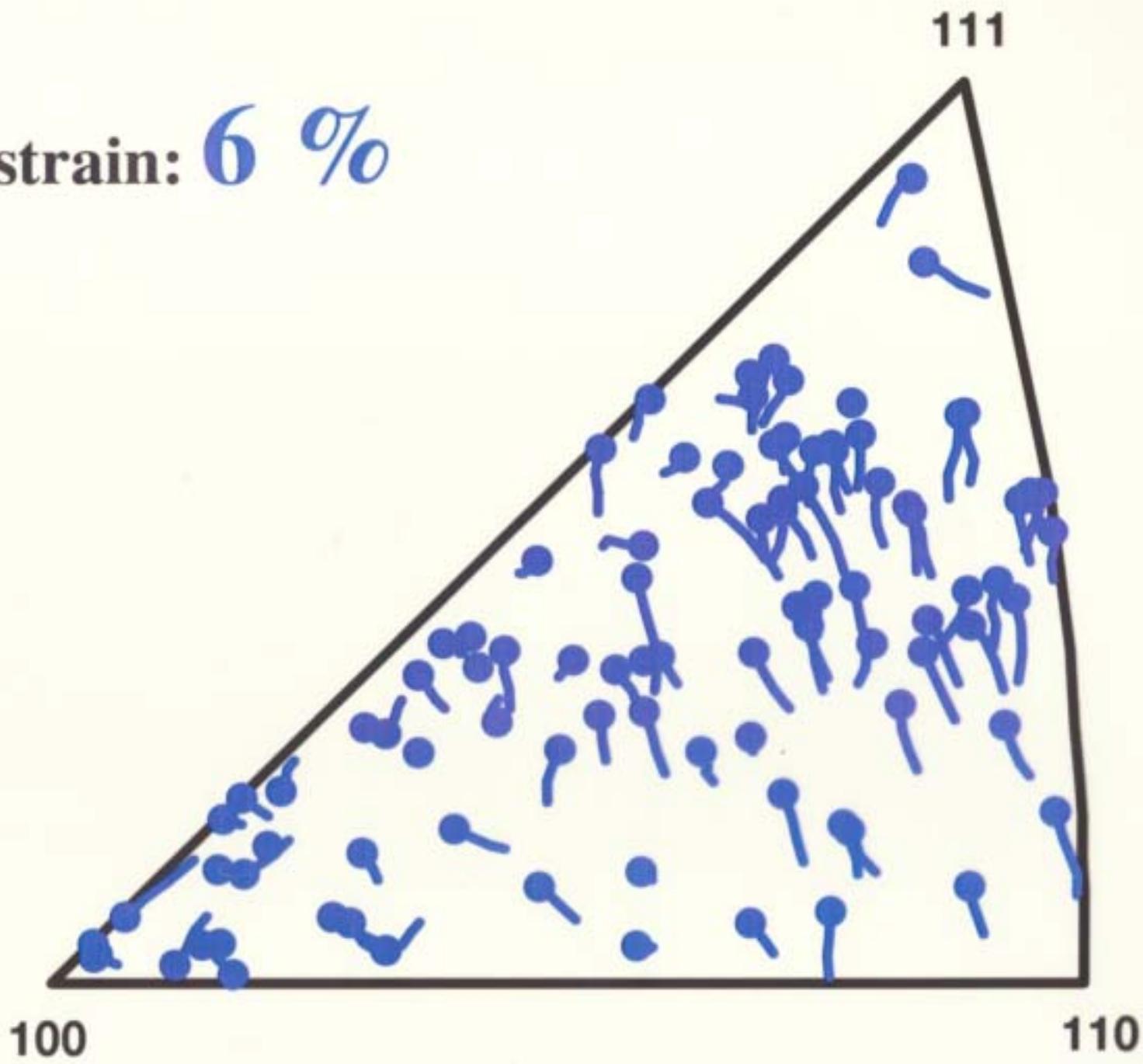


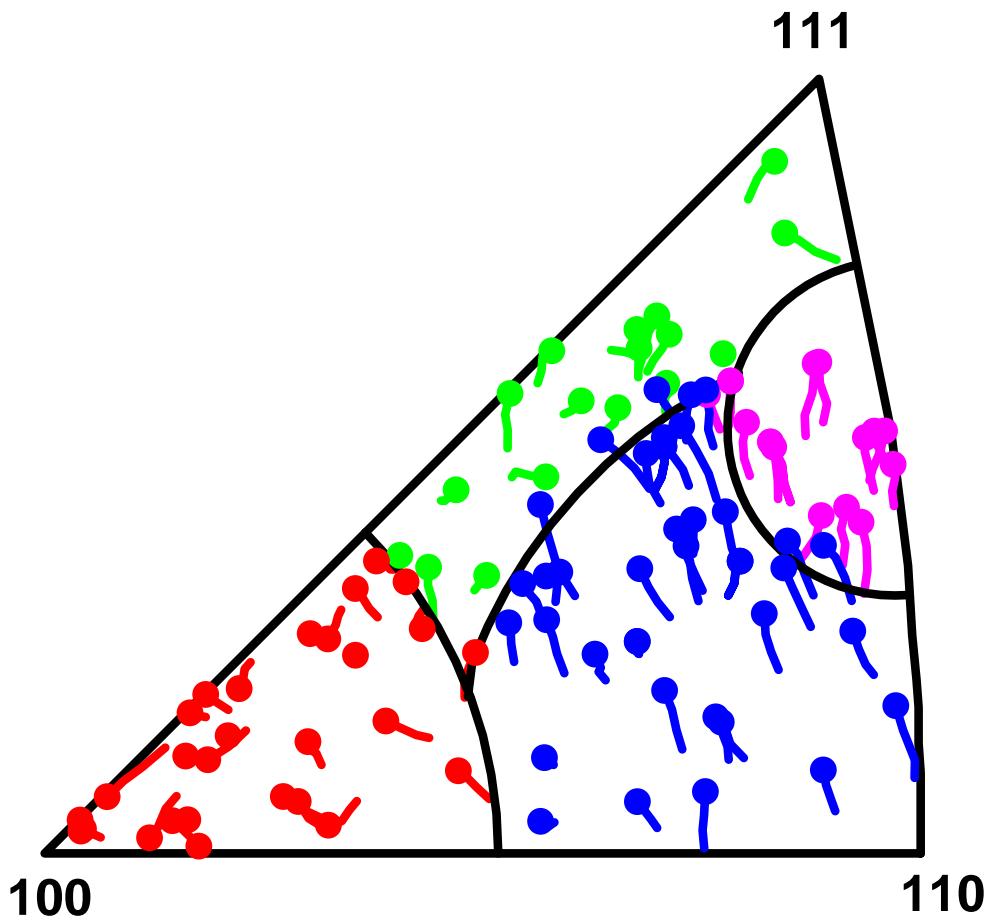
Rotation pathway of the tensile axis



Margulies, L., Winther, G., Poulsen H.F. 2001. In situ measurement of grain rotation during deformation of polycrystals. Science 291, 2392-2394.

Tensile strain: 6 %





Winther, G. Margulies, L., Schmidt, S., Poulsen, H.F., 2004, Lattice rotations of individual bulk grain Part II: Correlation with initial orientation and model comparison. *Acta. Mater.* In press.

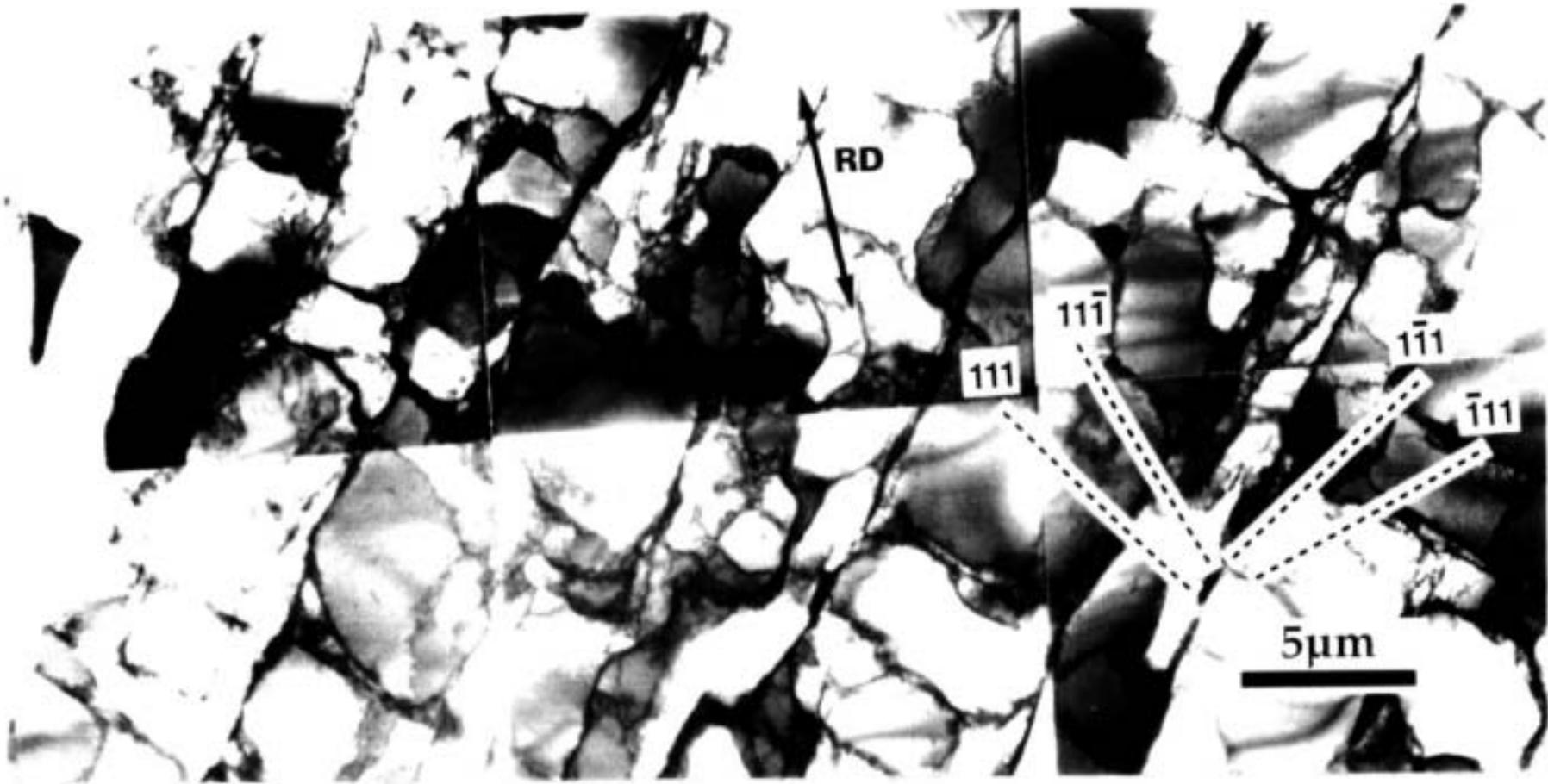
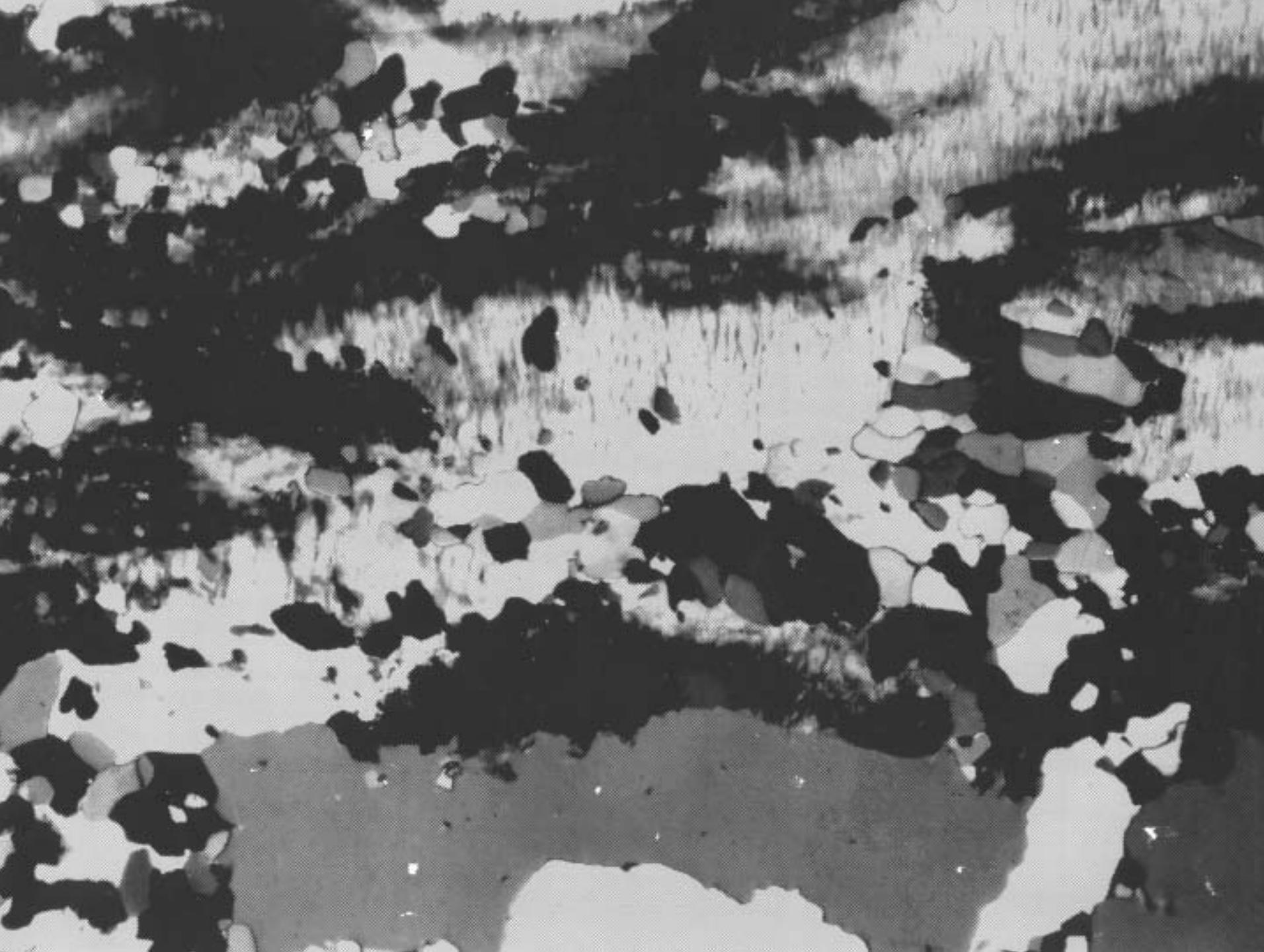


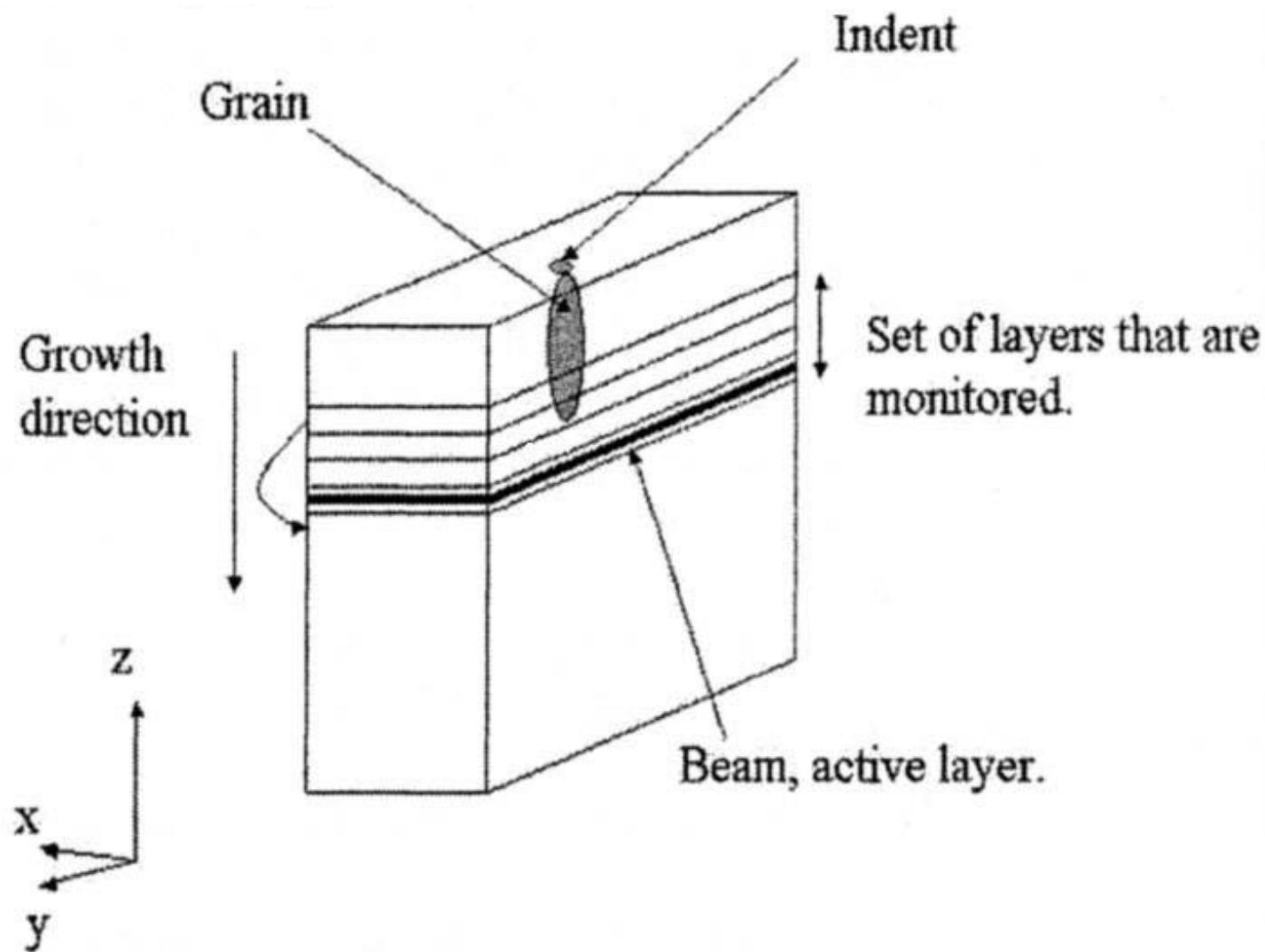
Figure 5 A complex cell blocks structure of 10% cold-rolled specimen in longitudinal plane vies. $ND/RD = (.36 .91 .21)/(.93 .35 .10)$, the nearest ideal orientation and the deviation are Cube (010)/[100] and 24.8 deg.

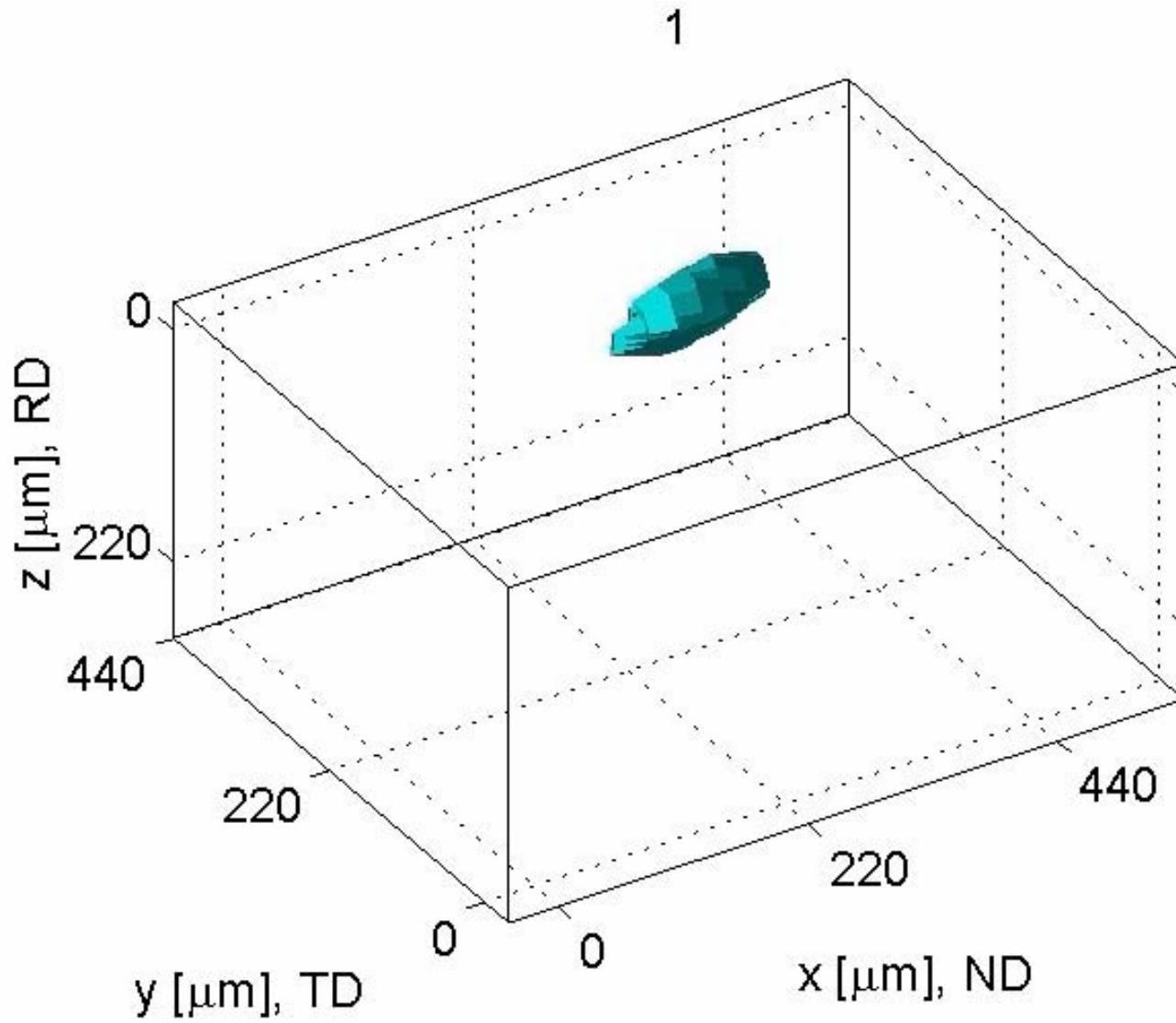
Recrystallization



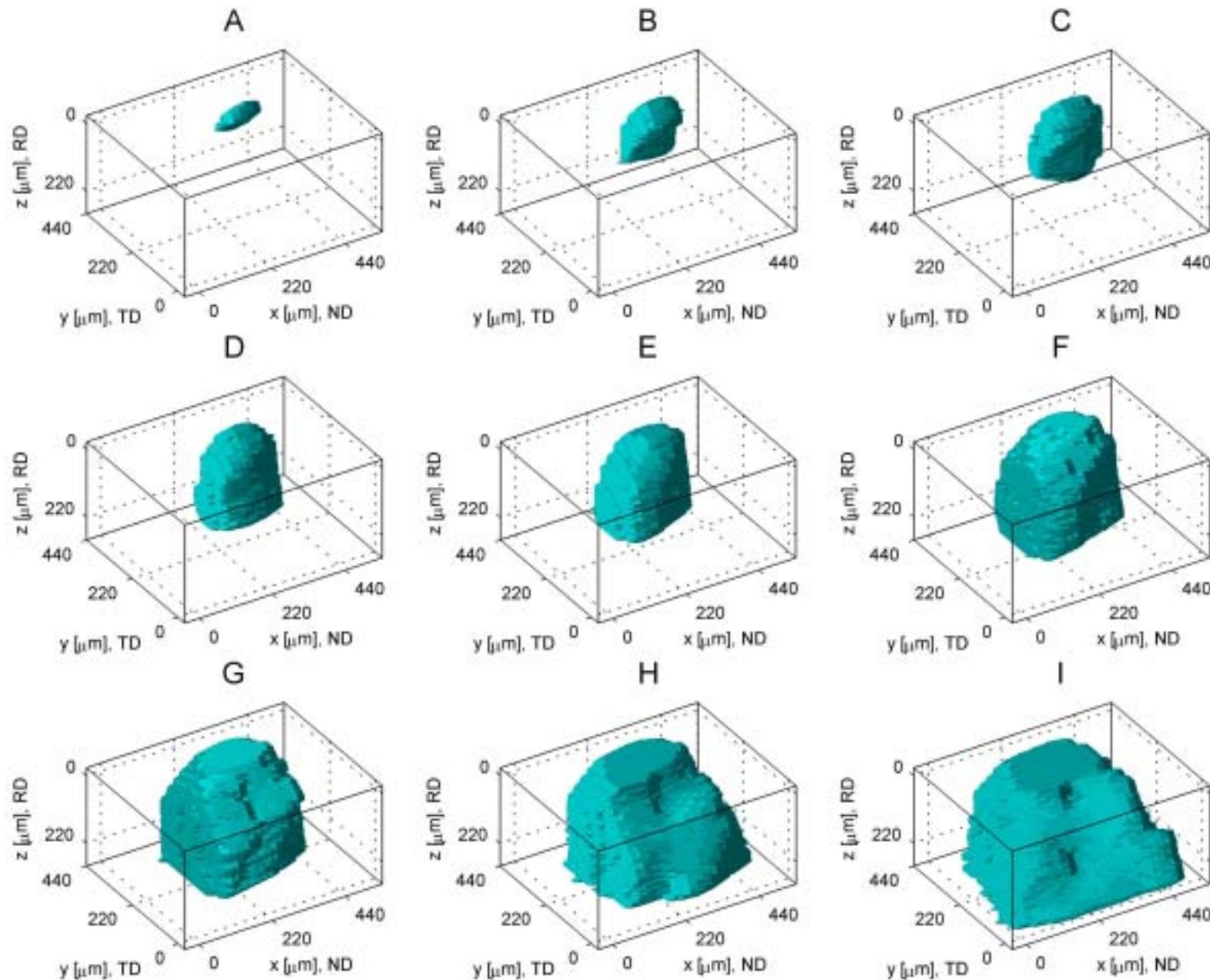
In-situ mapping in 3D of a growing nucleus

**Al single crystal ~ Goss orientation cr 40%
Nucleation controlled by hardness indents.**





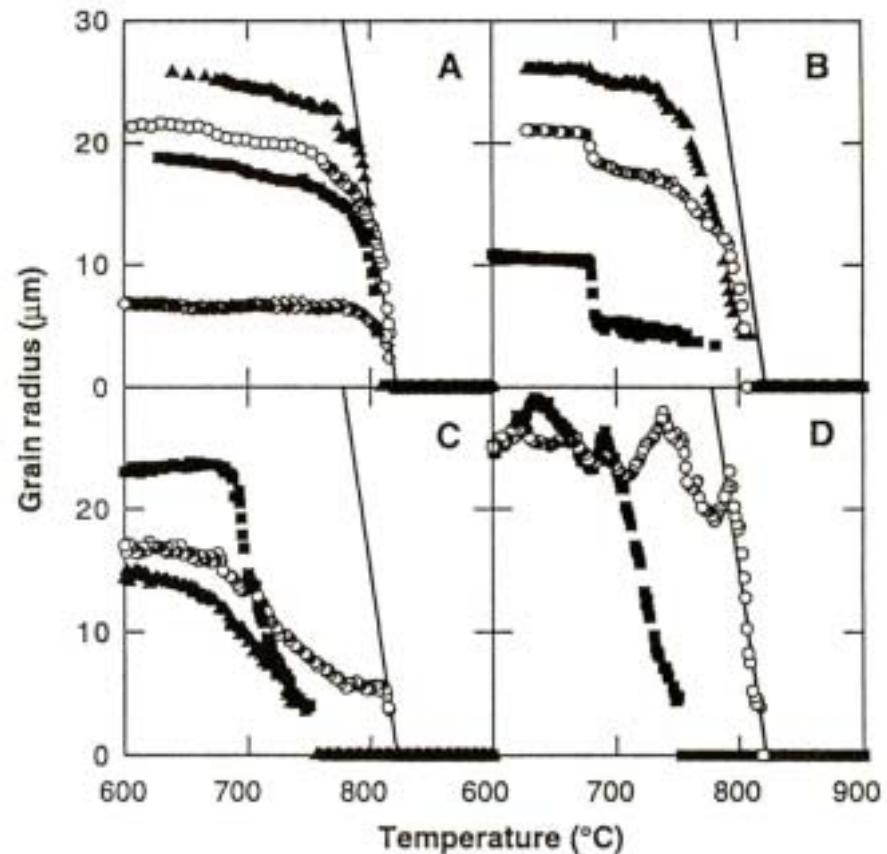
Schmidt, S., Nielsen, S.F., Gundlach, G., Margulies, L., Huang, X., Juul Jensen, D.,
Science, 2004, 229-232.



Phase Transformations

Grain Nucleation and Growth during phase transformation

Construction Steel
(0.21% C, 0.51% Mn, 0.20% Si)
Cooling: 900°C - 600°C
Low temperature: Ferrite + Cementite
High temperature: Austenite



S.E. Offerman et al. Science 298 (2002), 1003-1005

Outlook

- **Further exploitation and use of 3DXRD**
- **Improve spatial resolution**
 - New detector 1 μm x 2 μm x 2 μm
 - New beamline – 3DXRD **nanoscope**
- **Combine 3DXRD and Tomography**